Standardization of Norton Sound Trawl Survey Red King Crab Abundance Estimates

By

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OEO/ADA STATEMENT

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ABSTRACT

The National Marine Fisheries Service and the Alaska Department of Fish and Game have conducted seven Norton Sound trawl surveys for fish and invertebrate distribution and abundance information. Unfortunately, the trawl surveys have varied in their methodology such as the number of stations successfully towed, the definition of legal male red king crab, and the abundance estimation procedures implemented. This report reanalyzes each survey's red king crab catch information for the purpose of standardizing the legal male abundance estimates to allow more appropriate comparisons between surveys. In addition, for the first time, pre-recruit male red king crab abundances have been estimated for each survey.

INTRODUCTION

Numerous surveys have occurred in Norton Sound waters to assess the status of various stocks with potential or actual commercial importance. The National Marine Fisheries Service (NMFS) conducted triennial stock assessment trawl surveys of Norton Sound from 1976 to 1991. These surveys provided information on the distribution and abundance of demersal fish and invertebrates, and were summarized in Wolotira et al. (1977), Sample and Wolotira (1985), NMFS (1982), Stevens and MacIntosh (1986), Stevens (1989), and Stevens (1992).

The NMFS eliminated Norton Sound from the 1994 triennial survey due to budget constraints. In 1996, the ADF&G conducted the first Norton Sound trawl survey since the 1991 NMFS survey. This was the ADF&G's first trawl survey of Norton Sound, and was designed to provide information about spatial distribution, abundance, and population characteristics of red king crabs *Paralithodes camtschatica*, as well as other marine life. The distribution of red king crabs from the 1996 survey was described in Blau et al. (1996) with the related data on the abundance and biomass of red king crabs from the 1996 survey provided in Fair (1997).

Additionally, pot surveys in Norton Sound were conducted by the ADF&G in 1980, 1981, 1982, and 1985 (Lean and Brennan 1995). The pot surveys provided: (1) annual distribution, abundance, and size class information; and (2) pre-summer season information to fishery managers regarding stock size and structure.

A historical table was constructed that includes red king crab biomass and abundance estimates from all the pot and trawl surveys conducted in Norton Sound (Table 1). A problem with many of the population estimates provided in the historical table is that valid comparisons can not be made between surveys because of varying survey methodology. For example, the size definition for legal males has differed between some NMFS trawl surveys and from the ADF&G survey. The NMFS defined a legal male red king crab as ≥ 100 mm carapace length (CL) for the 1976, 1979, 1982, and 1985 surveys. Legal males were defined as ≥ 104 mm CL for the 1988 and 1991 surveys. The ADF&G defines legal male red king crabs as ≥ 121 mm carapace width (CW), which relates to approximately 104 mm CL. Additionally, the survey area coverage has varied between surveys (Figures 1 to 7).

Norton Sound red king crab population abundance estimates for legal males range from a low of 0.35 million crabs in 1982 (pot survey) to a high of 3.12 million crabs in 1976 (trawl survey), with a mean of 1.23 million (Table 1). For the purposes of this study, I will only focus on abundance estimates and will not attempt to estimate biomass. Many of the prior Norton Sound trawl surveys have not adequately provided sufficient paired length and weight information for accurately estimating biomass. I will, however, report the methodology used by the NMFS for estimating biomass to document inconsistency in calculating average weight of crab. Legal male biomass estimates range from a low of 1.27 million pounds in 1982 (pot survey) to a high of 8.11 million pounds in 1976 (trawl survey), with a mean of 3.66 million (Table 1).

The purpose of this study was to standardize all Norton Sound trawl survey abundance estimates for more reliable survey comparisons. Modeling and recent assessment work showed a lack of consistency highlighting the need to establish a standardized database for comparative purposes. Additionally, the relevant methodology and findings related to red king crab from each trawl survey have been summarized. Data files from all the NMFS surveys were given to the ADF&G and used to recalculate the population estimates of interest. Pot survey estimates were not adjusted in this report.

By standardizing all trawl surveys into comparable population estimates, the Norton Sound red king crab stock may be better understood. Before 1976, commercial fishing in Norton Sound for red king crabs was not conducted at a significant level. Therefore, the Norton Sound 1976 trawl survey estimate has been taken to represent the red king crab population at an unexploited level. The management goal has been to maintain the Norton Sound stock at 30-50% of the unexploited population of 8.11 million pounds of legal male crabs. However, it now appears that the 1976 estimate is not directly comparable to later estimates, and therefore, may not accurately represent the unexploited population level.

METHODS

Norton Sound trawl surveys were standardized by excluding catches from surveyed stations outside of the 1996 survey area (Figure 1). Additionally, legal male crabs were defined as ≥ 104 mm CL as done in Jie et al. (*in press*), pre-1 male crabs were defined as 90 mm to 103 mm CL, and pre-2 male crabs were defined as 76 mm to 89 mm CL.

The NMFS data files for 1976, 1979, and 1988 lacked tow distances for some surveyed tows, with resampled stations accounting for most of the missing data. For tows lacking the necessary tow distance information, the trimmed average tow distance for all other tows in that survey was substituted by first removing all outlying tow distances which differed from the overall mean tow distance by more than two standard deviations.

Population Estimates

Population abundance estimates for Norton Sound red king crabs were generated using the area-swept method (Alverson and Pereyra 1969). Variances were estimated assuming catch was binomially distributed (Seber 1982; page 22). The abundance was estimated for legal males, pre-1 males, and pre-2 males. Female abundance was not estimated because of the enormous variability in station catches due to their clumped distribution. Population estimates for stations

that were trawled multiple times in one survey incorporated the data by combining the catches and tow distances for each station resampled, thereby reducing the variance estimation. As done in Jie et al. (*in press*), if a station was not surveyed during a given year, its abundance was estimated as the average of abundances in the four adjacent survey stations. If more than two adjacent stations were not surveyed, the abundance of the non-surveyed station was assumed as zero. To summarize, abundance estimates for legal crabs were standardized using three approaches; these included defining legal males as ≥ 104 mm CL, only using catches within a standard area, and estimating the abundance for non-sampled stations, an approach which has not previously been done for Norton Sound trawl surveys except in Jie et al. (*in press*) to estimate total male crab abundance.

Using the area-swept method, the total catch in numbers, n, and the total area trawled, a, was computed for each area, summing across tows for those areas with multiple tows. Abundance for the jth area was then estimated as:

$$\hat{N}_j = n_j * \frac{A_j}{a_j}, \quad (1)$$

where A was the total area (Alverson and Pereyra 1969). The total abundance was estimated as:

$$\hat{N} = \sum_j \hat{N}_j . \quad (2)$$

The variance of $\hat{N}$ was estimated as:

$$\hat{V}(\hat{N}) = \sum_j \hat{N}_j \left(1 - \frac{a_j}{A_j}\right) \frac{A_j}{a_j} \quad (3)$$

(Seber 1982, page 22).

The population abundances are pre-molt, post-summer commercial fishery estimates. Although some of the surveys occurred during the early seasonal molting period, the majority of the survey catches occurred before most crabs had molted (Charlie Lean, ADF&G, personal communication). In all survey years except 1979 and 1996, the summer commercial fishery concluded before the trawl survey began. In 1979, the summer commercial fishery ended on July 31 and the trawl survey began on July 26. However, by July 26, commercial catches were negligible, and therefore, the population estimate for 1979 was not adjusted for harvests occurring from July 26 to July 31. In 1996, the summer commercial fishery operated from July 9 to September 2, and the trawl survey was conducted from August 7 to August 18. To account for the harvest that occurred after the trawl survey, the commercial harvest in numbers from August 19 to September 2 (N = 16,661) was subtracted from the trawl survey abundance estimate.

Biomass estimates were not generated because of the lack of sufficient paired weight and length data necessary for regression modeling. Some of the trawl surveys have weight and length data, but others do not. Rather than assume that the weight-length relationship is similar among years, or use the average weight of legal males captured in the summer commercial fishery, I chose not to estimate biomass in this study.

Surveys with Resampled Stations

In four of the Norton Sound trawl surveys, some stations were towed multiple times. These included the 1976, 1979, and 1988 NMFS surveys, and the 1996 ADF&G trawl survey.

The 1976 survey occurred over a greater span of time than any other Norton Sound trawl survey. In 1976, original and resampled tows occurred from September 2 to October 6. There were 17 stations in the standardized survey area trawled multiple times (Table 2), 15 containing red king crab catches. The number of days between tows for resampled stations ranged from 1 to 33 days. Population abundance estimates for the 1976 survey were generated for five scenarios to explore various data analysis options. The large number of days between some of the resampled stations probably violated the assumption that migration did not occur between tow dates for resampled stations.

- Scenario 1: Combine the catch and tow distances from ALL successful tows for resampled stations.
- Scenario 2: Only use the catch and tow distances from the FIRST successful tow for resampled stations.
- Scenario 3: Only use the catch and tow distances from the LAST successful tow (or last group of consecutive tows) for resampled stations.
- Scenario 4: Only use the catch and tow distances from the successful tows having the largest catch for resampled stations.
- Scenario 5: Adjust the historical estimate by multiplying it by the ratio of crabs ≥ 104 mm CL to those ≥ 100 mm CL. However, this approach does not standardize the population estimate by area, only by size.

The 1979 survey was the earliest survey conducted in Norton Sound occurring from July 26 to August 5. There were 16 stations in the standardized survey area trawled multiple times (Table 2), 10 containing red king crab catches. The number of days between tows for resampled stations ranged from one to six days. Because the 1979 Norton Sound trawl survey data are not complete in the NMFS database, approximately one-third of the data associated with the 1979 survey is unavailable. However, a memo dated August 8, 1979 from the NMFS to the ADF&G offers sufficient information regarding male red king crab catches from the 1979 survey to estimate abundance for those crabs ≥ 100 mm CL within the standardized survey area. However, the data required to estimate pre-1 and pre-2 male abundance is lacking.

The 1988 survey contained resampled stations that the NMFS report did not mention but which became apparent from the raw data files. There were four stations in the standardized survey area trawled multiple times (Table 2), three containing red king crab catches. The number of days between tows for resampled stations ranged from zero to four days.

The 1996 ADF&G trawl survey also included resampled stations. Unlike the resampled stations from the 1976, 1979, and 1988 surveys, station resampling in 1996 did not occur until all other

planned stations were completed. There were 21 stations in the standardized survey area trawled multiple times (Table 2), eight containing red king crab catches. The number of days between tows for resampled stations ranged from 4 to 11 days.

RESULTS

Table 2 compares all the Norton Sound trawl surveys in relation to survey dates, the type of sampling gear, the number of successful tows, the number of stations resampled, and the sampling time schedule (i.e., nighttime or daytime sampling). The earliest survey occurred in 1979 beginning on July 26 and the latest that any survey ended was October 7 in 1976. All of the NMFS trawl surveys used an 83-112 eastern otter trawl but the ADF&G trawl survey used a 400 eastern otter trawl. The total number of successful tows ranged from 53 in 1982 and 1991 to 192 in 1976. The number of resampled stations varied from zero in 1982, 1985, and 1991 to 21 in 1996. Sampling occurred on a 24-hour basis in the 1976, 1979, 1982 and 1988 surveys, but occurred during the daylight hours only in the 1985, 1991, and 1996 surveys.

Norton Sound trawl survey catches and standardized population abundances with their associated standard errors for red king crabs are presented in Table 3. For original tows, pre-2 male catches ranged from a low of 39 in 1991 and 1996 to a high of 82 in 1988; pre-1 male catches ranged from a low of 32 in 1996 to a high of 110 in 1976; legal male catches ranged from a low of 53 in 1996 to a high of 180 in 1976; and female catches ranged from a low of 98 in 1996 to a high of 256 in 1982.

The 1976 standardized legal male abundance was estimated for five scenarios. Legal abundance was estimated at about 1.57 million for Scenario 1, 1.19 million for Scenario 2, 1.74 million for Scenario 3, 2.68 million for Scenario 4, and 2.72 million for Scenario 5. Scenario 3 is believed to be the most appropriate model, and therefore, abundance estimates for pre-1 and pre-2 males were only generated using Scenario 3. Scenario 3 was chosen over the other scenarios since the final tow or group of final consecutive tows at a station is likely to have been more successful than earlier tows. Perhaps these stations were resampled because the scientific crew was not satisfied with the first tow. However, this type of information is not available in the 1976 survey report.

Population abundance estimates for pre-2 males have remained relatively stable over time (Figure 8). The 1976 and 1982 pre-2 male abundance estimates are similar at approximately 0.34 million, and then increase through 1988 to 0.57 million, dropping in 1991 to 0.29 million, and then increasing in 1996 to 0.45 million crabs.

Population abundance estimates for pre-1 males have decreased over time (Figure 9). In 1976 and 1982, pre-1 male abundance estimates were high at approximately 0.82 million crabs. Pre-1

male abundances dropped continually from the 1982 survey to the 1991 survey, reaching a low of 0.30 million crabs, and remaining near that level for the 1996 survey.

Population abundance estimates for standardized legal males have cycled over time (Figure 10). In 1976, the legal male abundance estimate was the highest at approximately 1.74 million crabs, and then it declined to 0.81 million in 1979 and remained between 0.80 and 1.05 million crabs through the 1988 survey. The legal male abundance estimate increased to 1.29 million crabs in 1991, and then fell to an overall low of 0.54 million in 1996.

The NMFS reports indicated that there were no significant differences between the day and night catches for red king crabs in the 1976 and 1979 trawl surveys. The 1982 and 1988 surveys also fished on a 24-hour basis but the reports made no mention of day or night red king crab catches.

Based on Figures 2-7 showing the legal male catches for all NMFS surveys, limiting the usable catches to only those stations located within the standardized survey area did not likely affect population estimates significantly for most surveys. All surveys conducted from 1979 to 1991 caught less than five legal male red king crabs outside of the standard survey area. The 1976 survey had the largest sampling distribution and consequently caught 43 legal male red king crabs outside of the standard survey area. This catch, however, was only 5% of the total legal male catch for the entire 1976 survey.

For some surveys, standardizing the size of legal male red king crabs affected the population abundance estimates substantially. Many of the NMFS reports defined legal male red king crabs as $\geq$ 100 mm CL, and increasing the legal size to $\geq$ 104 mm reduced legal male population estimates considerably. The percentage of males 100-103 mm CL ranged from 2-15% (average = 12%) for all surveys except 1979, which lacked the necessary data to make this estimate.

The abundance estimates for the 1976 to 1982 surveys were largely influenced by the non-sampled station estimation (Figure 11). The 1976 legal abundance estimate increased by 11%, the 1979 estimate by 15%, and the 1982 estimate was affected the most with a 23% increase in legal abundance. On the other hand, survey abundance estimates for legal males from 1985 to 1996 were only increased by 3-5%.

DISCUSSION

The trawl gear used in the 1996 Norton Sound trawl survey differed from prior surveys. The six NMFS surveys from 1976 to 1991 used an 83-112 trawl, whereas the 1996 survey used a 400 eastern. The 83-112 trawl has a similar footrope configuration to the 400 eastern and tows similarly over rough bottom. It is unlikely that catch selectivity differences exist between the 83-

112 trawl used in the past and the 400 eastern used in 1996 (Robert Otto, NMFS, personal communication).

I defined legal red king crab males as ≥ 104 mm CL based on a subjective analysis of winter and summer length frequencies for pre-recruit and recruit crab. For the winter and summer length data, 104 mm CL appeared to be the midpoint for the overlap in length frequencies between pre-recruit and recruit crab. That is, at 104 mm CL, there were approximately equal numbers of pre-recruit crab ≥ 104 mm CL as there were recruit crab less than 104 mm CL. The variability between years is uncertain and often difficult to measure because of the low sample sizes.

1976 NMFS Trawl Survey

The historically reported abundance estimate from the 1976 Norton Sound NMFS trawl survey for legal male crabs is 3.12 million from 555 captured legal males (Table 1). The standardized abundance estimate is 1.74 million legal males from 794 captured legal males (Table 3); this is 56% of the historical estimate (Figure 11). Before abundance was estimated for the non-sampled stations, the standardized estimate was only 50% of the historical estimate because many of the standard stations in the west were not trawled. The large number of legal males caught at station I12 (N = 538) with its corresponding large abundance estimate caused the non-sampled station immediately to the west to have a large estimated abundance, accounting for the majority of the increase.

There is a large discrepancy between the historical and standardized estimates of legal males captured during the 1976 survey. The NMFS defined legal male crabs as ≥ 100 mm CL for the 1976 survey, which accounts for most of the difference in abundance estimates. Apparently, the NMFS did not use data from all successful tows in Norton Sound because the legal male catch shown in Table 1 is less than the data files indicate. It is not stated in the 1976 report how the resampled catches were treated in the abundance estimation procedure. Approximately three-quarters of the standardized legal males were captured in resampled tows. Station I12 near Nome accounted for most of the standardized legal males captured (N = 538) during the entire 1976 Norton Sound survey. Figure 7 shows that 45 legal male crabs were caught beyond the standard sampling area and that the largest catch of legal male crabs outside the standard area was 10 at station F08. Removing these 45 crabs from the abundance estimation procedure resulted in a lower standardized legal male estimate but to a lesser extent than the exclusion of crabs 100–103 mm CL (N = 117).

Biomass estimates for red king crabs were made by the NMFS using regression equations of weight on length derived from the 1976 Norton Sound survey. They used the equation

$$W = aL^b,$$

where W is weight, L is length, and a and b are estimated parameters.

1979 NMFS Trawl Survey

The historically reported abundance estimate from the 1979 Norton Sound NMFS trawl survey for legal male crabs is 0.84 million from 194 captured legal males (Table 1). The standardized abundance estimate is 0.81 million legal male crabs from 176 captured legal males (Table 3); this is 97% of the historical estimate (Figure 11). Before abundance was estimated for the non-sampled stations, the standardized estimate was 82% of the historical estimate because, similar to the 1976 survey, many of the standard stations in the west were not trawled.

The historical estimate from Table 1 is not presented in the 1979 NMFS survey report. The report gives an estimate for all sized red king crabs caught in all of Norton Sound as 1.43 million in Table 28 (page 64). Table 29 (page 66) of the 1979 report gives abundance estimates for red king crabs grouped by size using a different methodology than Table 28 for resampled catches. Unfortunately, the chosen methodology is not discussed. The estimate from Table 29 for males ≥ 100 mm CL is 0.77 million for all stations in Norton Sound.

The NMFS defined legal male crabs as ≥ 100 mm CL for the 1979 survey. The percentage of male crabs 100-103 mm CL is unknown for this survey because of incomplete data files. Nearly one-half of the area-standardized legal males caught in the 1979 survey were captured in resampled tows. Figure 6 shows that only two legal male crabs were caught beyond the standard sampling area. Thus, the discrepancy between the historical and area-standardized legal male abundance estimates can be mostly explained from the exclusion of crabs 100-103 mm CL and the methodology used for treating resampled catches. Standardization for the 1979 abundance estimate is only an area standardization. Biomass estimates for red king crabs were made by the NMFS using regression equations of weight on length derived from the 1979 Norton Sound survey.

1982 NMFS Trawl Survey

The historically reported abundance estimate from the 1982 Norton Sound NMFS trawl survey for legal male crabs is 0.97 million from 107 captured legal males (Table 1). The standardized abundance estimate is 0.88 million legal male crabs from 97 captured legal males (Table 3); this is 90% of the historical estimate (Figure 11). Before abundance was estimated for the non-sampled stations, the standardized estimate was 70% of the historical estimate because many of the standard stations in the west and southwest were not trawled. The 1982 standardized abundance estimate increased more from non-sampled station abundance estimation than any other survey because of the large abundances surrounding these stations.

Figure 5 shows that only one standardized legal male crab was caught beyond the standard survey area indicating that the discrepancy between the historical and standardized legal crab abundance estimate did not result from the exclusion of station catches outside of the standardized survey area. The 1982 NMFS report does not define legal male red king crab for this survey. Legal males were likely defined as ≥ 100 mm CL, similar to the 1976 and 1979 surveys. The larger legal male size class is probably the main cause for the substantial drop in legal male abundance from the historical to the standardized abundance estimate. The historical table shows that only 107 legal males were caught during the 1982 survey but the NMFS data files indicate a catch of 136 males ≥ 100 mm CL and 98 males ≥ 104 mm CL. The discrepancy is unexplained, but if the NMFS had defined legal males as ≥ 103 mm CL, the sample size would be 107, which is exactly what the historical table shows.

The NMFS report for the 1982 Norton Sound trawl survey gives no abundance estimates, only a map of red king crab catches with no distinction between sex and/or size. There is also no weight information presented either in the report or in the data files. It is unclear how the NMFS derived the biomass estimates in Table 1 for the 1982 trawl survey.

1985 NMFS Trawl Survey

The historically reported abundance estimate from the 1985 Norton Sound NMFS trawl survey for legal male crabs is 1.20 million from 163 captured legal males (Table 1). The standardized abundance estimate is 1.05 million legal male crabs from 139 captured legal males (Table 3); this is 87% of the historical estimate (Figure 11). Before abundance was estimated for the non-sampled stations, the standardized estimate was 85% of the historical estimate.

The 1985 NMFS report does not clearly define legal male red king crabs. The report defines legal males as ≥ 100 mm CL in two places, but Table 2 (page 26) of the 1985 report gives the estimate for males ≥ 104 mm CL as 1.20 million crabs. However, I believe the 1.2 million estimate from Table 1 actually represents the abundance of crabs ≥ 100 mm CL. The historical table states that 163 legal males were captured, and the five males ≥ 104 mm CL caught outside of the standard area (Figure 4) reduces the number of legal males to 158 crabs. Removing the number of crabs 100-103 mm CL (N = 25) based on data file information, the number of legal males drops to 133 crabs. Because 133 crabs is similar to the 132 crabs shown as the number of standardized legal males from Table 3, I believe that the legal male estimate presented in Table 1 for the 1985 survey is not for crabs ≥ 104 mm CL as it states, but rather for crabs ≥ 100 mm CL. The NMFS generated biomass estimates for red king crabs using regression equations of weight on length derived from the 1985 Norton Sound trawl survey.

1988 NMFS Trawl Survey

The historically reported abundance estimate from the 1988 Norton Sound NMFS trawl survey for legal male crabs is 1.04 million from 141 captured legal males (Table 1). The standardized abundance estimate is 0.98 million legal male crabs from 138 captured legal males (Table 3); this is 94% of the historical estimate (Figure 11). Before abundance was estimated for the non-sampled stations, the standardized estimate was 91% of the historical estimate.

Like this report, the 1988 NMFS report defined legal males as ≥ 104 mm CL. Figure 3 shows that three standardized legal male crabs were caught beyond the standard survey area which accounts for only a small percentage of the discrepancy between the historical and standardized legal crab abundance estimates. The NMFS report does not explain how the resampled catches were treated, and in fact, fails to even mention their existence. Considering that only three legal males were captured in resampled tows, it seems unlikely that this in conjunction with the three legal males captured outside of the standardized area could explain the observed discrepancy. Thus, the reduction in legal male abundance from the historical estimate to the standardized estimate cannot be fully explained. The NMFS generated 1988 biomass estimates for red king crabs using regression equations of weight on length derived from the 1985 Norton Sound NMFS survey and/or the ADF&G pot surveys.

1991 NMFS Trawl Survey

The historically reported abundance estimate from the 1991 Norton Sound NMFS trawl survey for legal male crabs is 1.38 million from 178 captured legal males (Table 1). The standardized abundance estimate is 1.29 million legal male crabs from 166 captured legal males (Table 3); this is 93% of the historical estimate (Figure 11). Before abundance was estimated for the non-sampled stations, the standardized estimate was 89% of the historical estimate.

Like this report, the 1991 NMFS report defined legal males as ≥ 104 mm CL. Figure 2 shows that eight standardized legal male crabs were caught beyond the standard survey area which accounts for only about one-half of the discrepancy between the historical and standardized legal crab abundance estimates. Thus, the reduction in legal male abundance from the historical estimate to the standardized estimate cannot be fully explained. The NMFS generated 1991 biomass estimates for red king crabs using regression equations of weight on length derived from the 1985 Norton Sound NMFS survey and/or the ADF&G pot surveys.

1996 ADF&G Trawl Survey

The reported abundance estimate from Fair (1997) for the 1996 Norton Sound ADF&G trawl survey for legal male crabs is 0.53 million from 67 captured legal males (Table 1). The standardized abundance estimate is 0.54 million legal male crabs from 67 captured legal males (Table 3); this is just slightly greater than 100% of the historical estimate (Figure 11). Abundance estimation for the non-sampled stations accounts for 3% of the standardized estimate, but 16,661 crabs were removed from the legal male abundance estimate to account for the survey terminating before the commercial fishery closed.

CONCLUSIONS

Standardizing the NMFS trawl surveys makes it more appropriate to compare estimates between surveys. Adjusting the legal size to males ≥ 104 mm CL affected the abundance estimates significantly, especially for the 1982 survey, a year of high recruitment. Standardizing the survey area affected the 1976 survey estimates because of the large area this survey covered, but did not appear to significantly influence other trawl survey estimates. Estimating the abundances of non-sampled stations significantly influenced surveys from 1976 to 1982, but had only a limited impact thereafter.

This analysis tempers the optimism of early surveys that served to justify the development of the Norton Sound red king crab fishery. However, 18 years of commercial harvest data supports the continuation of a small fishery with low exploitation rates. The analysis also serves to reinforce the importance of documenting methodology and assumptions when estimates are generated.

LITERATURE CITED

Alverson, D.L. and W.T. Pereyra. 1969. Demersal fish explorations in the northeastern Pacific Ocean. J. Fish. Res. Board Can. 26:1985-2001.

Blau, S.F., L. J. Watson, and J. Blackburn. 1996. The 1996 Norton Sound red king crab trawl survey. Alaska Department of Fish and Game, Regional Information Report No. 4K96-54, Kodiak.

Fair, L.F. 1997. Analysis of red king crab data from the 1996 ADF&G trawl survey of Norton Sound. Alaska Department of Fish and Game, Regional Information Report No. 3A97-10, Anchorage.

Jie, Z., G.H. Kruse, and L. Fair. *In Press.* Using multiple data sets to assess red king crab in Norton Sound, Alaska: length-based stock synthesis. In Fishery Stock Assessment Models. Alaska Sea Grant College Program, 98:01.

Lean, C. and B. Brennan. 1995. 1995 Norton Sound District shellfish report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Regional Information Report No. 3A95-31, Anchorage.

National Marine Fisheries Service (NMFS). 1982. Cruise results: cruise no. MF-82-3 NOAA R/V *Miller Freeman* (Norton Sound - northeastern Bering Sea crab - groundfish survey). National Marine Fisheries Service, unpublished report. December 1982.

Sample, T.M. and R. J. Wolotira, Jr. 1985. Demersal fish and shellfish resources of Norton Sound and adjacent waters during 1979. National Marine Fisheries Service, Northwest and Alaska Fisheries Center, NOAA Technical Memorandum NMFS F/NWC-89. October 1985. 208 pages.

Seber, G.A.F. 1982. The Estimation of Animal Abundance and related parameters. Charles Griffin & Company Limited, England.

Stevens, B.G. and R.A. MacIntosh. 1986. Analysis of crab data from the 1985 NMFS survey of the northeast Bering Sea and Norton Sound. National Marine Fisheries Service, Northwest and Alaska Fisheries Center, NWAFC Processed Report 86-16. September 1986.

Stevens, B.G. 1989. Analysis of crab data from the 1988 NMFS survey of Norton Sound and the northeast Bering Sea. National Marine Fisheries Service, Northwest and Alaska Fisheries Center, unpublished Report. February 1989.

Stevens, B.G. 1992. Results of the 1991 NMFS survey of red king crab in Norton Sound. National Marine Fisheries Service, Alaska Fisheries Science Center, unpublished memorandum to the State of Alaska. May 1992.

Wolotira, R.J., Jr., T.M. Sample, and M. Morin, Jr. 1977. Demersal fish and shellfish resources of Norton Sound, the southeastern Chukchi Sea, and adjacent waters in the baseline year 1976. National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Processed Report. October 1977. 292 pages.

Table 1. Results of the population assessment surveys conducted for red king crab in Norton Sound since 1976.

Year	Date	Research Agency	Gear	Effort	Number of Red King Crabs Captured [a]			Population Estimates of Legal Male Crabs [c]	
					Sublegal Males	Legal Males [b]	Females	Numbers	Pounds
1976	**9/2 - 9/5, 9/16 - 10/6**	**NMFS**	**Trawl**	**158 Tows**	**768**	**555**	**180**	**3,119,800**	**8,111,480**
1979	**7/26 - 8/5**	**NMFS**	**Trawl**	**71 Tows**	**46**	**194**	**40**	**837,241**	**2,511,723**
1980 [d]	7/4 - 7/14	ADF&G	Pots	397 Lifts	443	3,290	158	1,900,000	6,600,000
1981	6/28 - 7/14	ADF&G	Pots	718 Lifts	4,097	3,415	1,933	1,285,195	4,755,221
1982	7/6 - 7/20	ADF&G	Pots	689 Lifts	5,019	2,001	424	353,273	1,271,783
1982	**9/5 - 9/11**	**NMFS**	**Trawl**	**50 Tows**	**322**	**107**	**265**	**970,646**	**2,620,744**
1985	7/1 - 7/14	ADF&G	Pots	642 Lifts	6,086	4,645	181	907,579	2,414,644
1985	**9/16 - 10/1**	**NMFS**	**Trawl**	**78 Tows**	**266**	**163**	**151**	**1,203,000**	**3,369,000**
1988	**8/16 - 8/30**	**NMFS**	**Trawl**	**82 Tows**	**258**	**141**	**218**	**1,037,000**	**3,038,000**
1991	**8/22 - 8/30**	**NMFS**	**Trawl**	**53 Tows**	**202**	**178**	**105**	**1,384,000**	**4,009,000**
1996	**8/7 - 8/18**	**ADF&G**	**Trawl**	**69 Tows**	**250**	**67**	**168**	**534,446**	**1,603,339**

[a] Number of crabs captured on ADF&G pot surveys represent data standardized for a 24-hour soak.

[b] Legal male red king crabs were defined as ≥ 106 mm in carapace length for the 1976 NMFS survey; 105 mm for the 1979 and 1985 NMFS survey; and ≥ 121 mm in carapace width for all ADF&G surveys.

[c] Population estimates are valid for the date of the survey. (i.e., either before or after the summer commercial fishery).

[d] The 1980 estimate has been revised from the original estimate of 13.4 million pounds. The original estimate was thought inaccurate due to under-reporting of recovered tagged crabs.

Table 2. Norton Sound trawl survey dates, gear type, total number of successful tows, number of resampled stations, and the sampling time schedule.

Year	Dates	Gear Type	Total Number of Successful Tows	Number of Resampled Stations	Sampling Time
1976	9/2 - 9/5, 9/16 – 10/6	83-112 Eastern Otter Trawl	192	17	24-Hour Basis
1979	7/26 - 8/5	83-112 Eastern Otter Trawl	115	16	24-Hour Basis
1982	9/5 - 9/11	83-112 Eastern Otter Trawl	53	0	24-Hour Basis
1985	9/16 - 10/1	83-112 Eastern Otter Trawl	78	0	Daylight Hours
1988	8/16 - 8/30	83-112 Eastern Otter Trawl	82	4	24-Hour Basis
1991	8/22 - 8/30	83-112 Eastern Otter Trawl	53	0	Daylight Hours
1996	8/7 - 8/18	400 Eastern Otter Trawl	69	21	Daylight Hours

Table 3. Reanalyzed results from population assessment surveys for red king crabs in Norton Sound since 1976.

Year	Date	Research Agency	Gear	Number of Red King Crabs Captured [a,e]				Population Abundance Estimates[c]			Standard Errors		
				Pre-2 Males	Pre-1 Males	Legal Males [b]	Females	Pre-2 Males	Pre-1 Males	Legal Males	Pre-2 Males	Pre-1 Males	Legal Males
1976 [e]	**9/2 - 9/5, 9/16 – 10/7**	**NMFS**	**Trawl**	**58(38)**	**110(213)**	**180(614)**	**101(35)**	**331,555**	**808,091**	**1,742,755**	**44,653**	**70,094**	**104,941**
1979 [f]	**7/26 - 8/5**	**NMFS**	**Trawl**	**N/A**	**N/A**	**90(86)**	N/A			**809,799**			**61,176**
1980 [d]	7/4 – 7/14	ADF&G	Pots			3,290	158			1,900,000			
1981	6/28 - 7/14	ADF&G	Pots			3,415	1,933			1,285,195			
1982	7/6 - 7/20	ADF&G	Pots			2,001	424			353,273			
1982	**9/5 - 9/11**	**NMFS**	**Trawl**	**42**	**107**	**97**	**256**	**356,724**	**832,581**	**877,722**	**50,116**	**76,454**	**79,907**
1985	7/1 - 7/14	ADF&G	Pots			4,645	181			907,579			
1985	**9/16 - 10/1**	**NMFS**	**Trawl**	**63**	**94**	**139**	**139**	**466,858**	**707,140**	**1,051,857**	**58,598**	**71,999**	**87,931**
1988	**8/16 - 8/30**	**NMFS**	**Trawl**	**82(0)**	**69(1)**	**135(3)**	**212(2)**	**565,255**	**493,030**	**978,748**	**62,339**	**58,224**	**82,083**
1991	**8/22 - 8/30**	**NMFS**	**Trawl**	**39**	**42**	**166**	**105**	**294,801**	**303,682**	**1,287,486**	**46,648**	**46,960**	**98,101**
1996 [e]	**8/7 - 8/18**	**ADF&G**	**Trawl**	**39(36)**	**32(17)**	**53(14)**	**98(70)**	**452,580**	**325,699**	**536,235**	**52,324**	**47,338**	**69,647**

[a] Number of crabs captured on ADF&G pot surveys represent data standardized for a 24-hour soak.

[b] Legal male red king crabs were defined as ≥ 121.8 mm (4.75 in) in carapace width for the pot surveys and the 1996 ADF&G trawl survey, and ≥ 104 mm for all of the NMFS trawl surveys except the 1979 survey which defined legal males as ≥ 100 mm.

[c] Population estimates are valid for the date of the survey (i.e., either before or after the summer commercial fishery).

[d] The 1980 pot survey estimate has been revised from the original estimate of 13.4 million pounds which was thought inaccurate due to an under-reporting of recovered tagged crabs.

[e] The 1976, 1979, and 1996 catches include resampled stations (in parenthesis). The 1979 and 1996 population estimates incorporated resampled stations by combining catches and tow distances for each station resampled.

[f] Pre-1 and pre-2 male, and female data is not available for the 1979 NMFS trawl survey and the legal male abundance estimate is fully standardized.

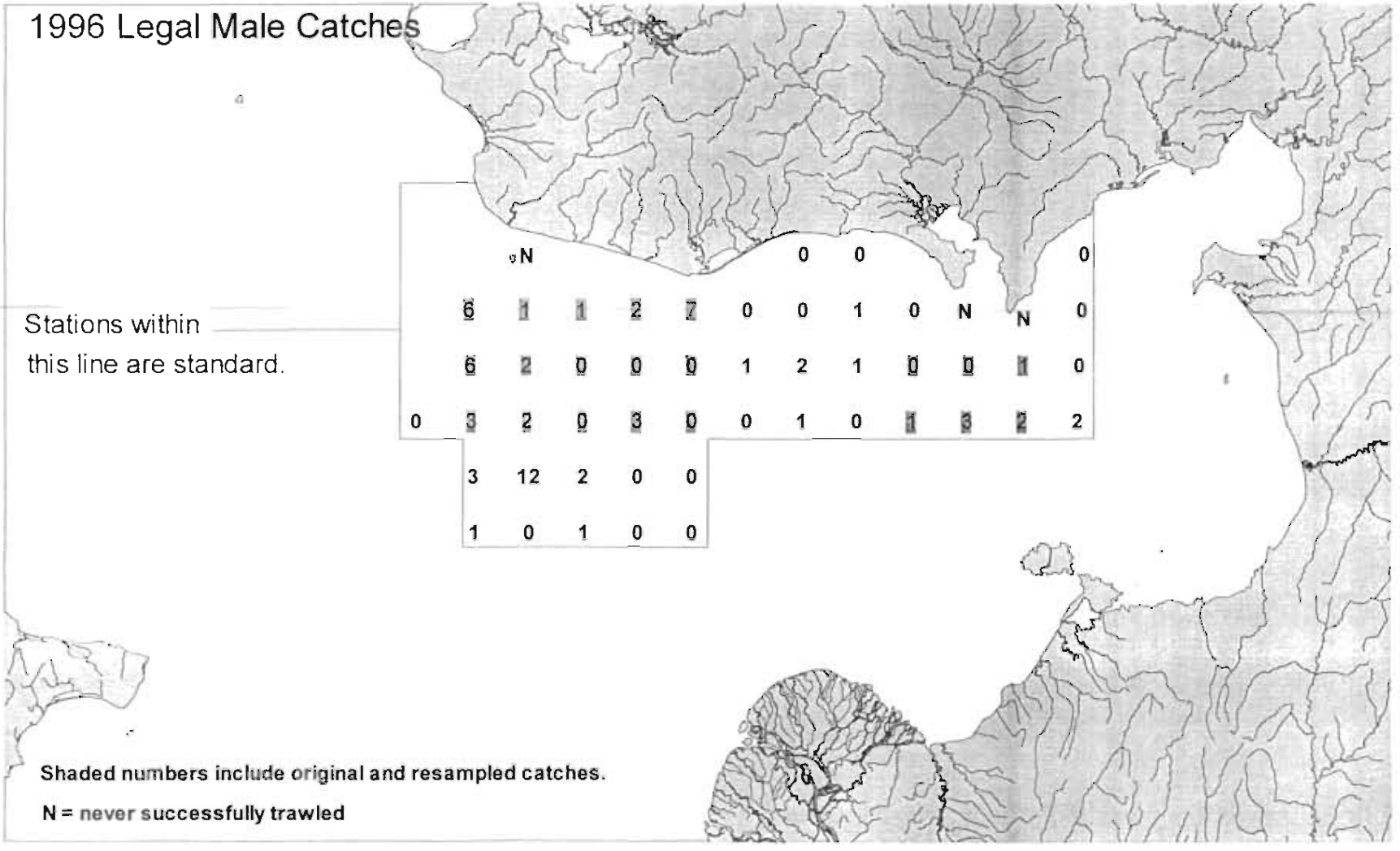

Figure 1. Norton Sound map showing legal male catches for red king crabs from stations sampled during the 1996 ADF&G trawl survey.

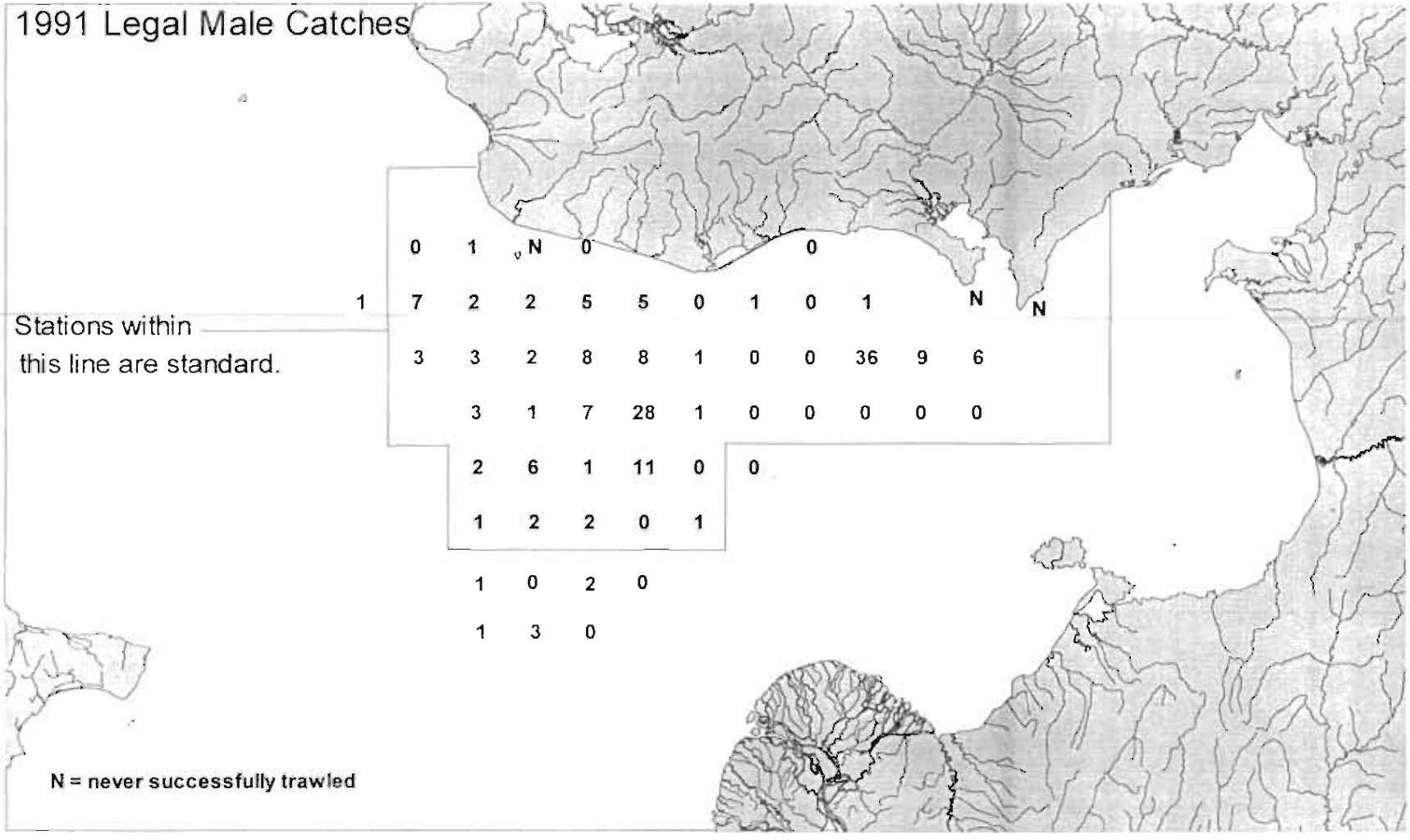

Figure 2. Norton Sound map showing legal male catches for red king crabs from stations sampled during the 1991 NMFS trawl survey.

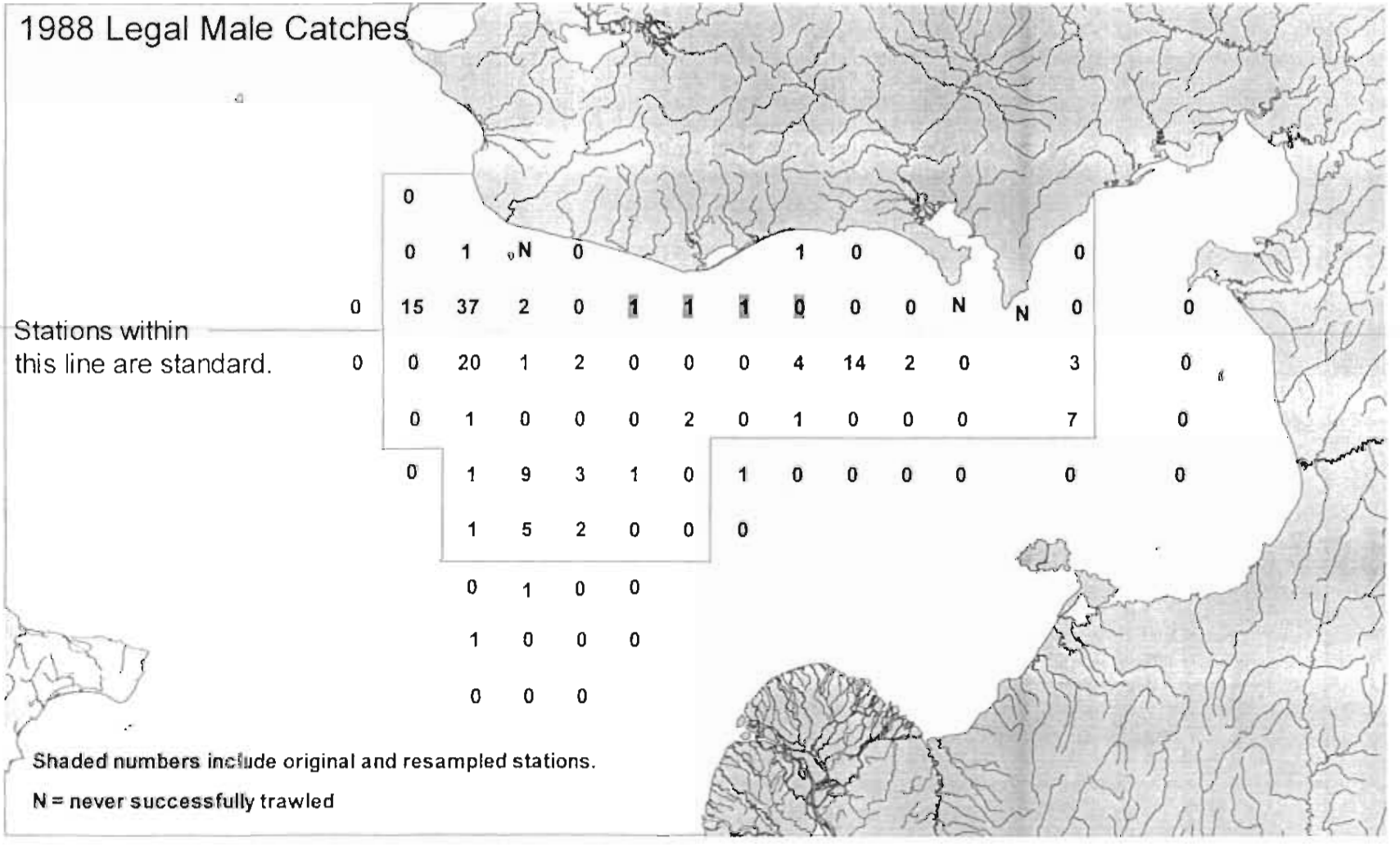

Figure 3. Norton Sound map showing legal male catches for red king crabs from stations sampled during the 1988 NMFS trawl survey.

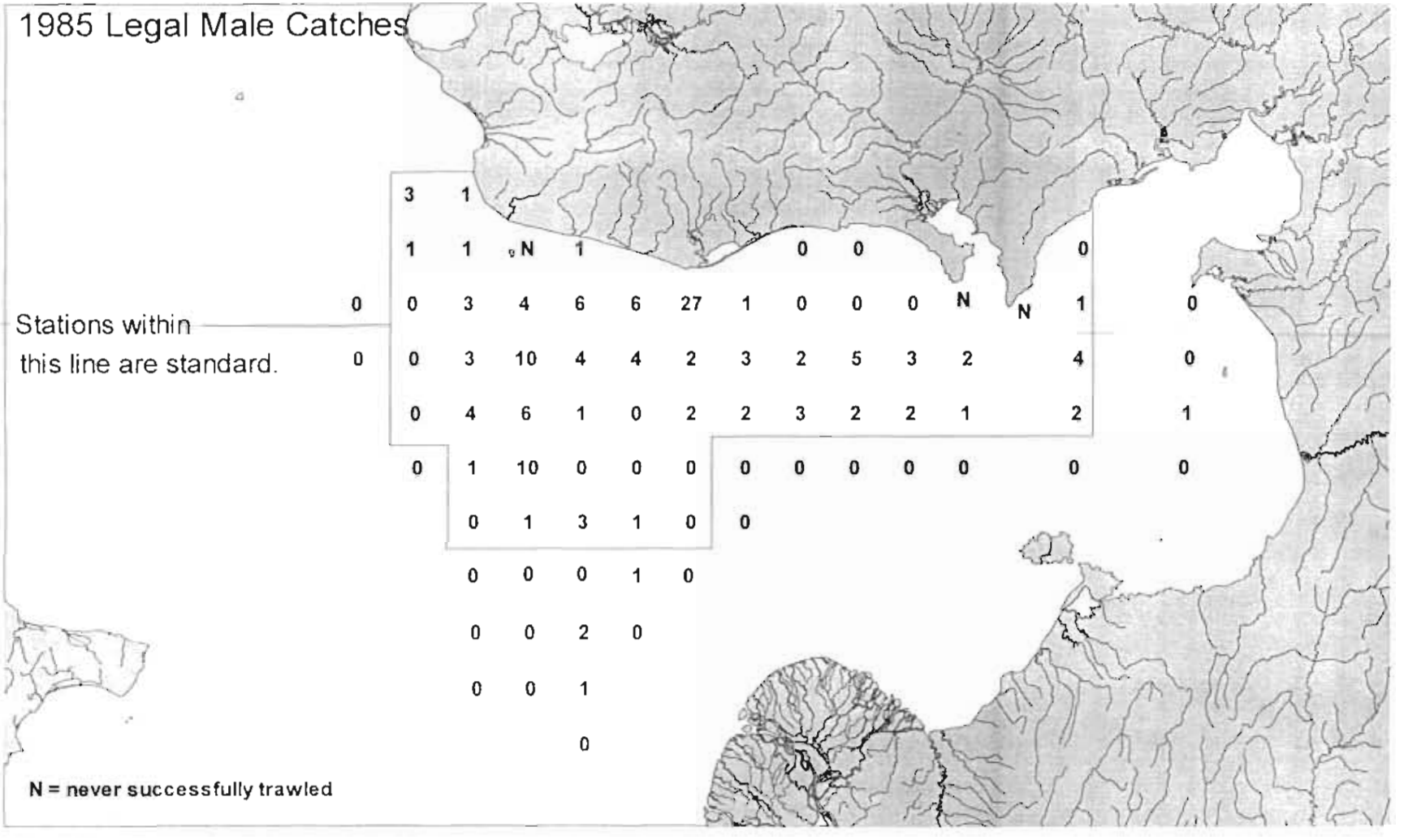

Figure 4. Norton Sound map showing legal male catches for red king crabs from stations sampled during the 1985 NMFS trawl survey.

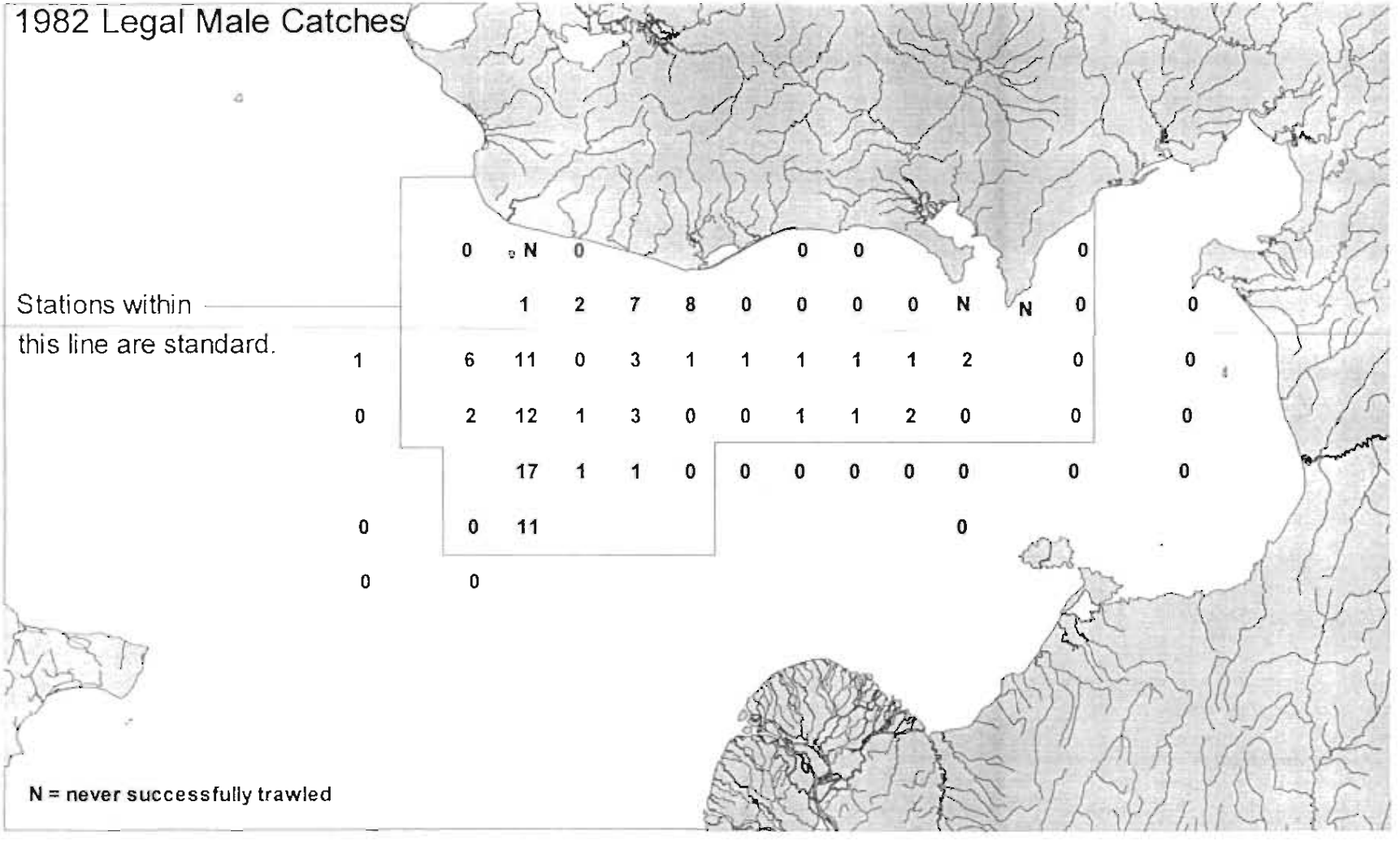

Figure 5. Norton Sound map showing legal male catches for red king crabs from stations sampled during the 1982 NMFS trawl survey.

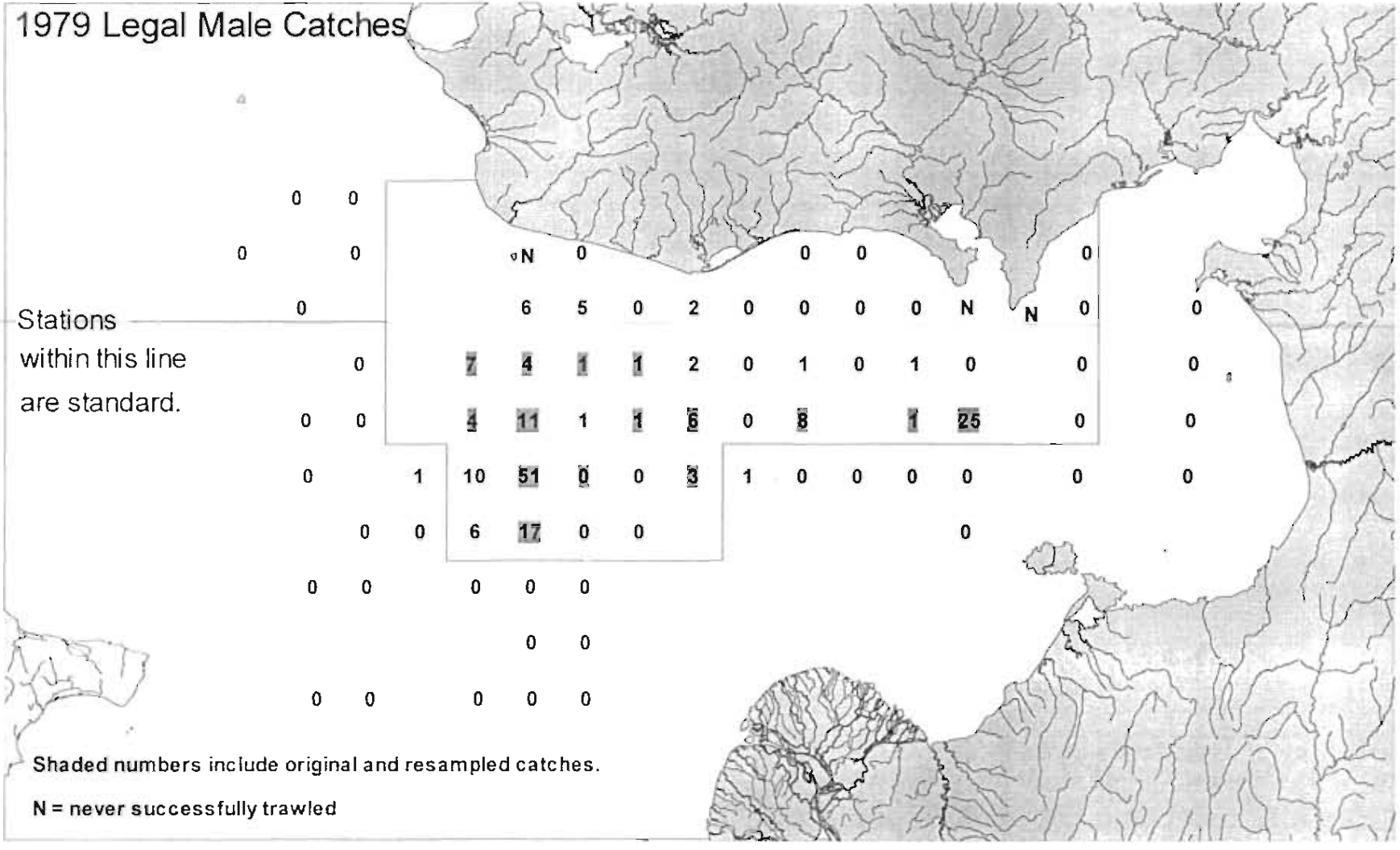

Figure 6. Norton Sound map showing legal male catches for red king crabs from stations sampled during the 1979 NMFS trawl survey.

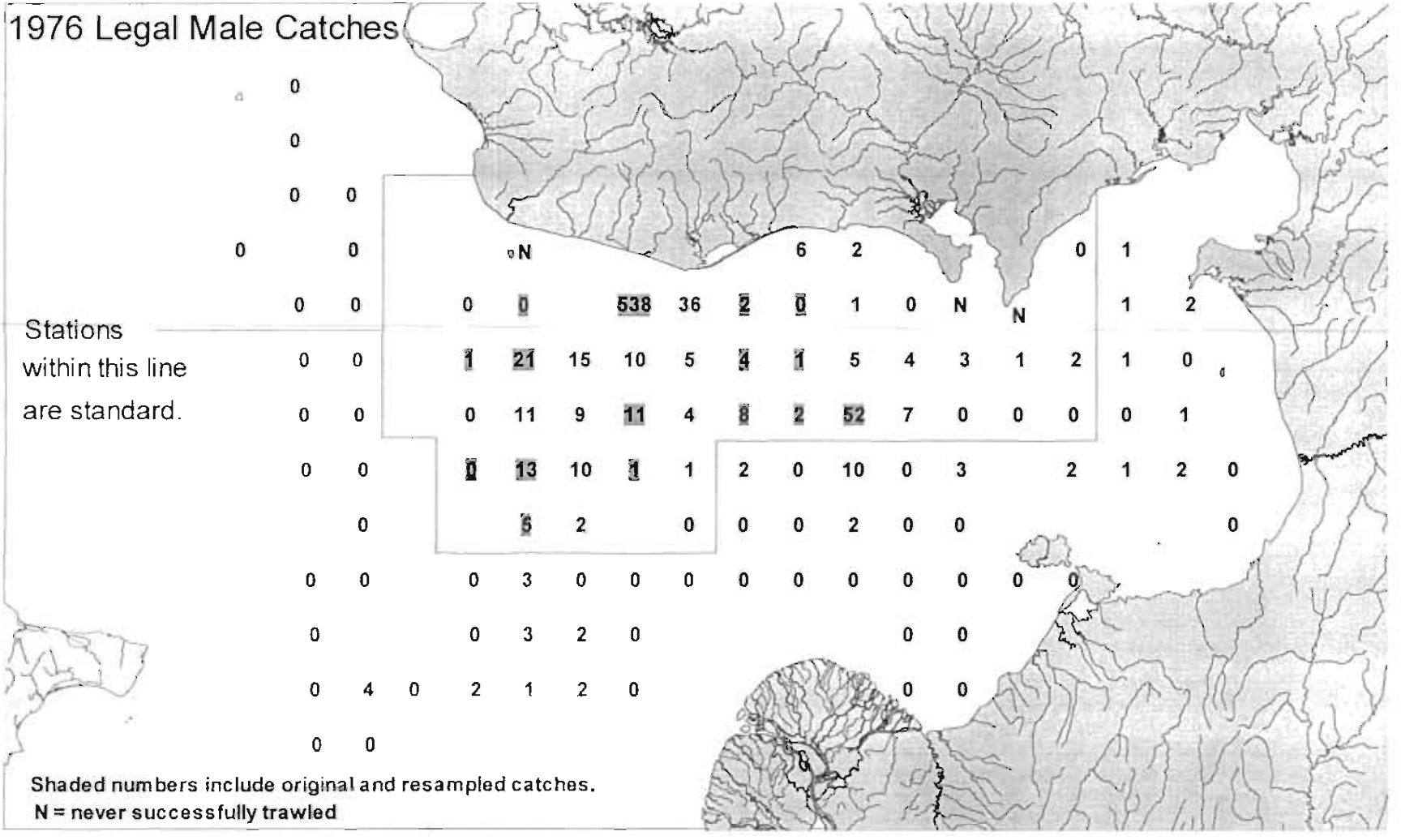

Figure 7. Norton Sound map showing legal male catches for red king crabs from stations sampled during the 1976 NMFS trawl survey.

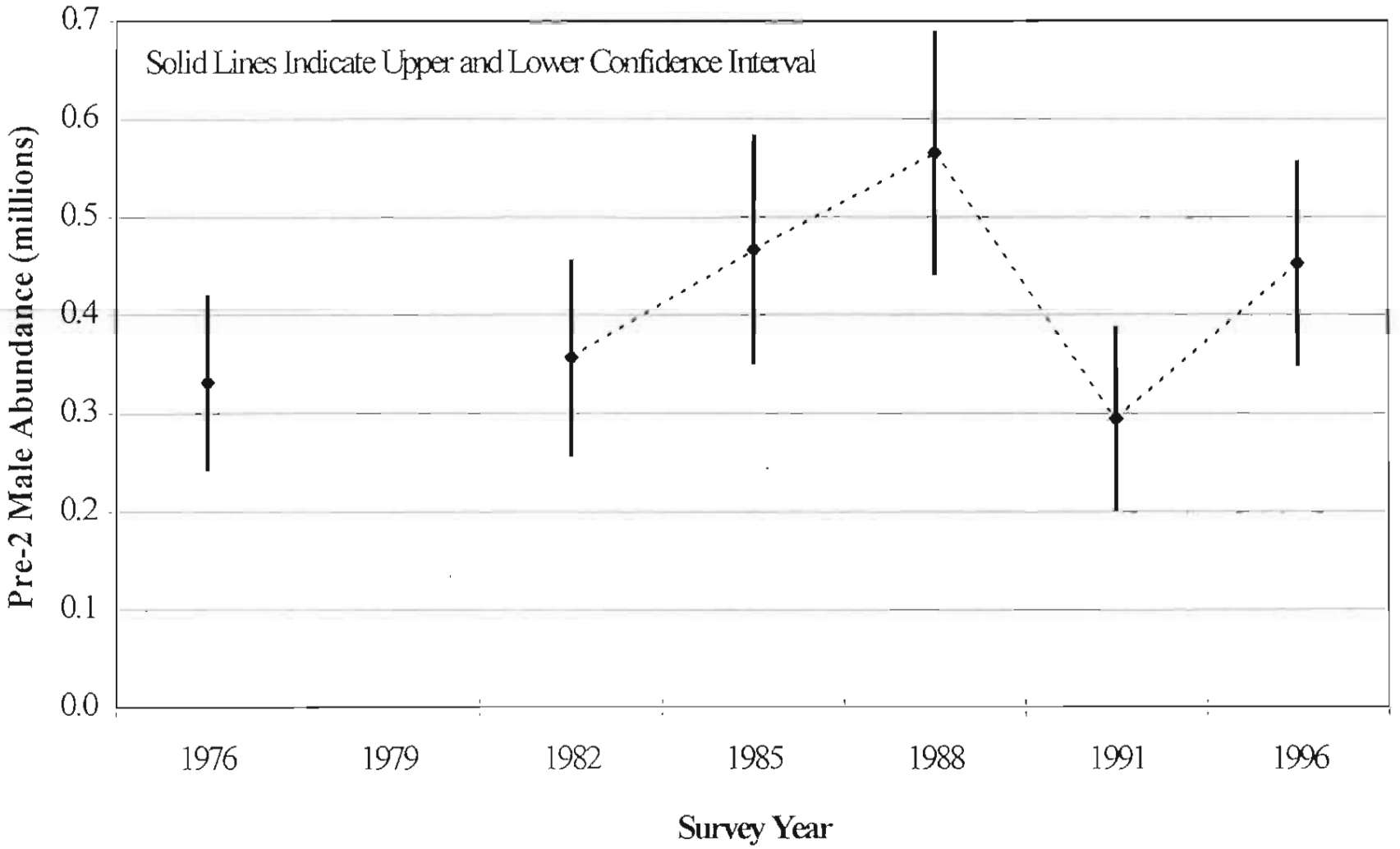

Figure 8. Standardized pre-2 male red king crab abundance estimates with 95% confidence intervals for the 1976-1996 Norton Sound trawl surveys.

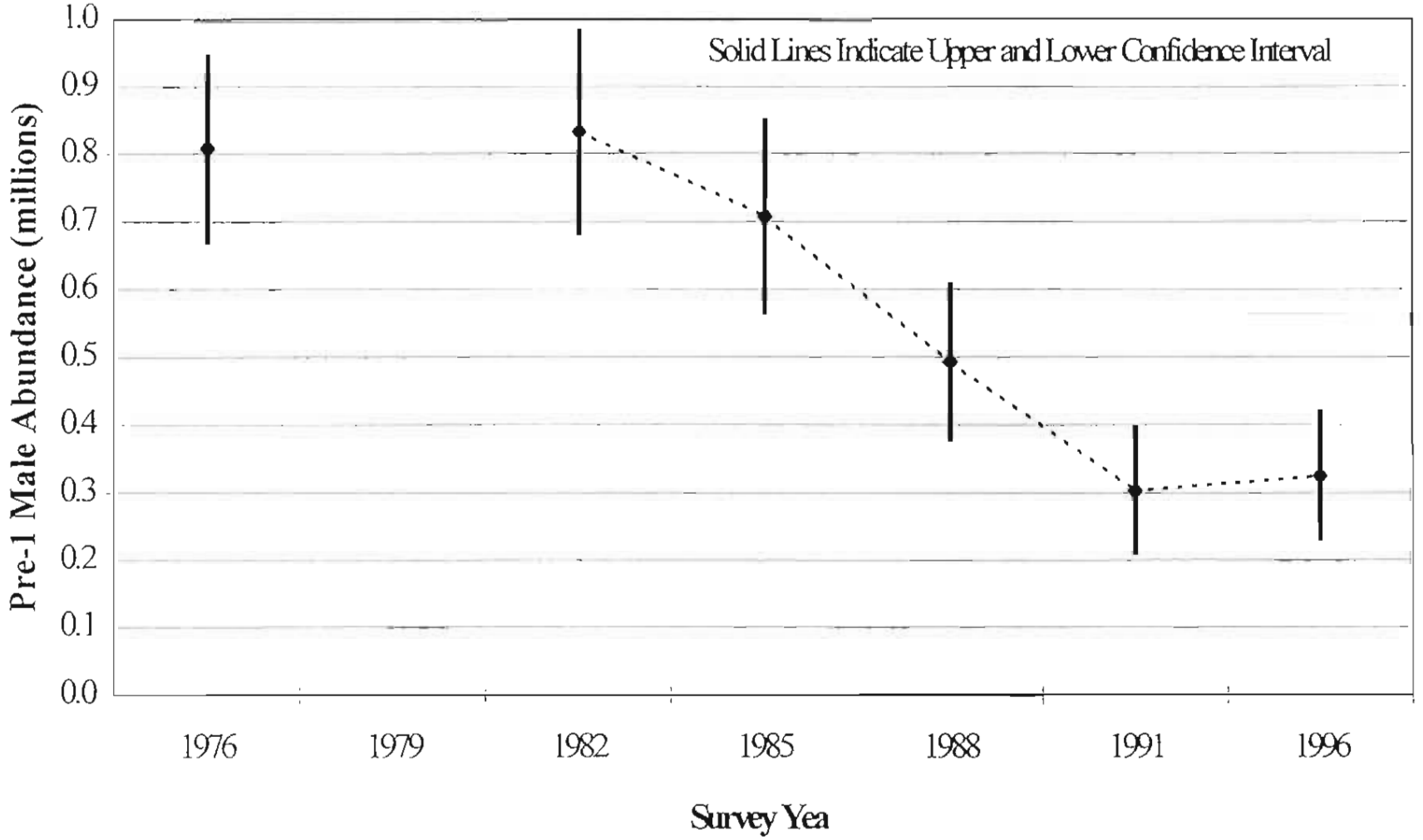

Figure 9. Standardized pre-1 male red king crab abundance estimates with 95% confidence intervals for the 1976-1996 Norton Sound trawl surveys.

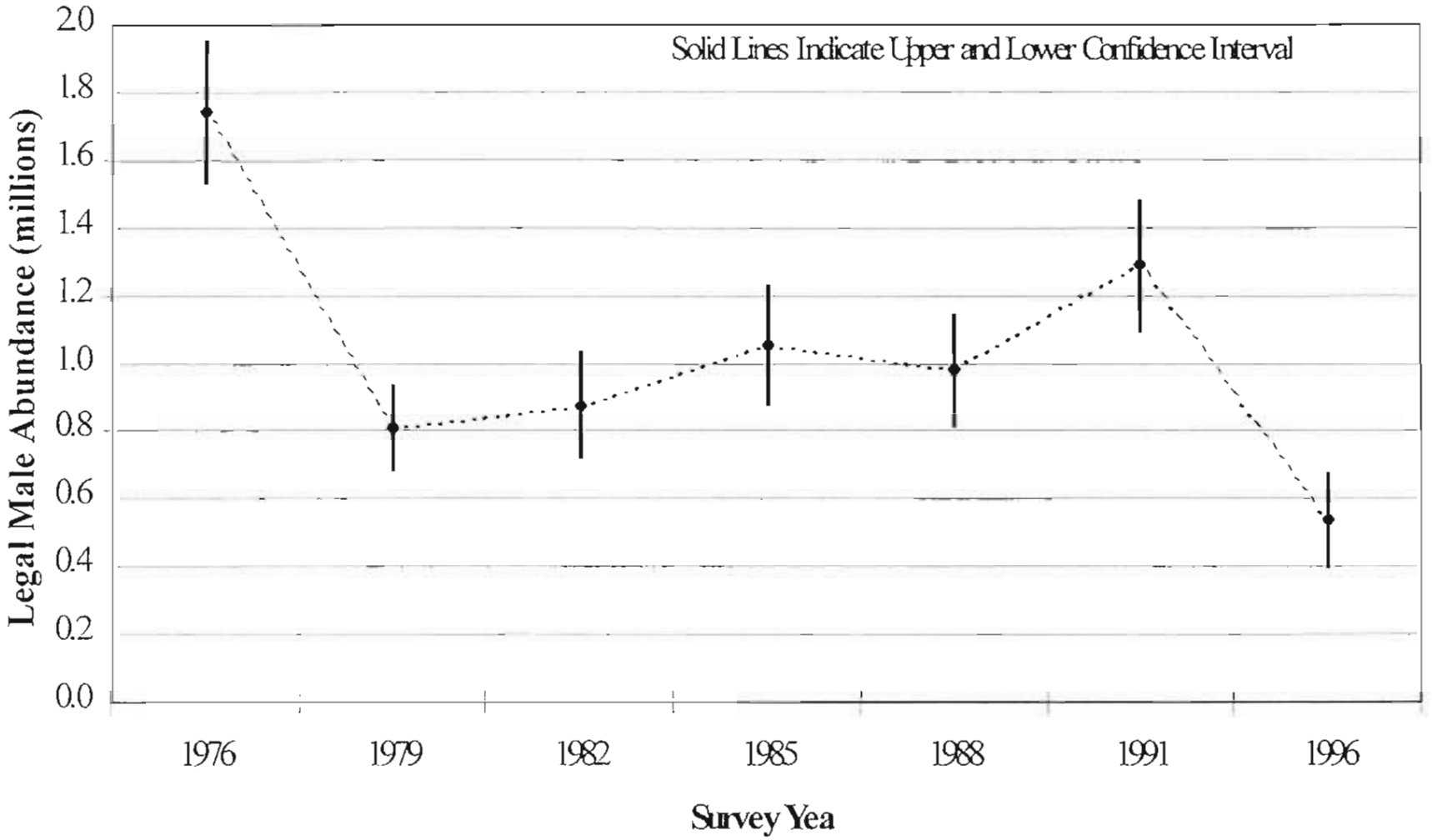

Figure 10. Standardized legal male red king crab abundance estimates with 95% confidence intervals for the 1976-1996 Norton Sound trawl surveys.

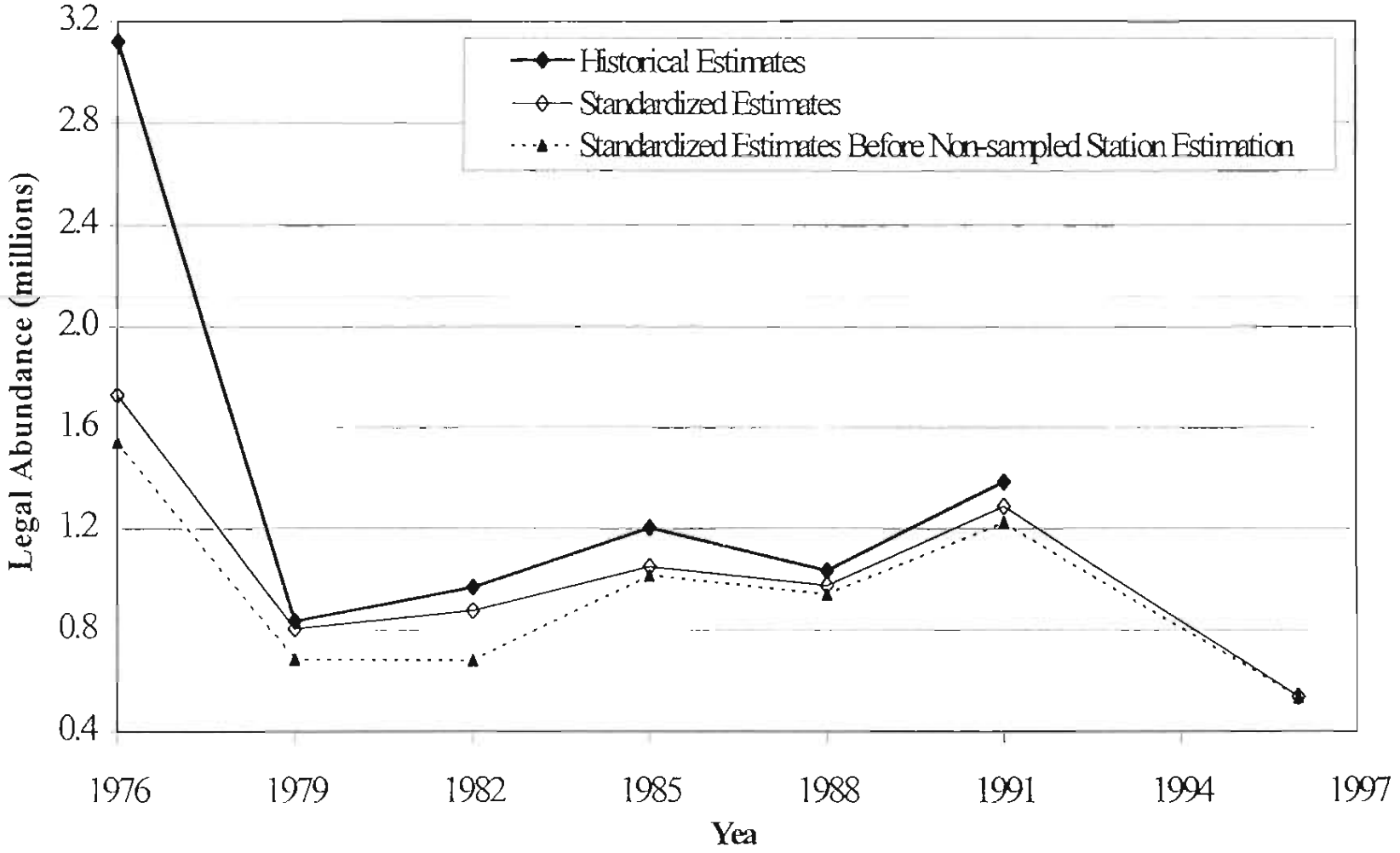

Figure 11. Historical and standardized red king crab legal male abundance estimates for the 1976-1996 Norton Sound trawl surveys.